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(54) Title of Invention: Exhaust Emission Control System for Variable Cylinder System Engines

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(72) Inventor: Shin Sugasawa
3-5-20 Nakahara, Isogo-ku, Yokohama City, Kanagawa Prefecture

(72) Inventor: Haruhiko Iizuka
2-50-4 Hairando, Yokosuka City, Kanagawa Prefecture

(72) Inventor: Junichiro Matsumoto
3-68 Oppama Higashi-cho, Yokosuka City, Kanagawa Prefecture

(71) Applicant: Nissan Motor Corp. Ltd.
2 Takara-cho, Kanagawa-ku, Yokohama City

(74) Agent: Masayoshi Goto, patent attorney

Specification

Title of Invention

Exhaust Emission Control System for Variable Cylinder System Engines

Claim(s)

An exhaust emission control system for a variable cylinder system engine comprised of a variable cylinder system control circuit that shuts off the fuel supply to at least one of the cylinder groups comprised of a specified number of cylinders depending on engine load; oxygen sensors and three-way catalysts that are provided in the exhaust passages of multiple cylinders belonging to the groups of multiple cylinders mentioned above to control the air-fuel ratio when the engine is operated under the partial cylinder mode; and an oxygen sensor and a three-way catalyst which are located in the merged section of the exhaust passages downstream of the exhaust passages mentioned above to control the air-fuel ratio when the engine is operated under the full cylinder mode; a unique feature of which is that the system is equipped with a switching device that switches the active cylinder group whenever the engine operating mode changes from full cylinder mode to partial cylinder mode.

Detailed Explanation of the Invention

This invention concerns the exhaust emission control system of variable cylinder system engines equipped with a variable cylinder control system that varies the number of cylinders to which fuel is supplied depending on engine load, and an air-fuel ratio control system for exhaust emission control, whereby the switching is made between the inactive cylinder group and the active cylinder group whenever the engine runs under full cylinder mode; the purpose of which is to improve the driving feeling.

In general, whenever an engine is operated under a heavily loaded condition, engine fuel economy tends to improve. This is the reason for the use of a variable cylinder system for a multiple cylinder engine. When it is operated under a light load condition, the fuel supply to a partial group of its cylinders is shut off so that the load for the remaining active cylinder group can be increased by the load corresponding to the inactive cylinders. This results in a relative increase in load per cylinder

leading to improvement in the overall fuel economy of the engine.

On the other hand, there is a system known as an engine exhaust emission control means in which a three-way catalyst is installed in the exhaust system, while the oxygen concentration of the exhaust gas is detected to achieve feedback control of the air-fuel ratio to become approximately equal to the stoichiometric air-fuel ratio, so that the three-way catalyst can perform oxidation of HC and CO as well as reduction of NOx at the same time with high efficiency. When this particular exhaust emission control system is applied to a variable cylinder system engine, especially under a partial cylinder mode when a partial group of its cylinders is made inactive, the oxygen concentration in the exhaust gas becomes excessively high and different from that in the actual active cylinders supplied with fuel. This results from air exhausted from the inactive cylinders without combustion, which forces the control to decrease the air-fuel ratio.

In order to circumvent this problem, oxygen sensors and 3-way catalysts are installed separately for the split exhaust passages, one for the active cylinder group and the other for the inactive cylinder group, so that the air-fuel ratio can be feedback-controlled independently of each other group of cylinders, while the feedback control can be stopped for the inactive cylinder group during the partial cylinder mode.

This system has the problem that the three-way catalyst in the inactive cylinder group is cooled during the partial cylinder mode by the exhaust air. When this partial cylinder mode is continued for a long time, the catalyst temperature becomes lower than the activation temperature needed for catalytic reaction, leading to a potential inability to achieve the required reaction efficiency when the engine running condition calls for the full cylinder mode.

In order to address this problem, the inactive cylinder group is alternated with the active cylinder group during engine operation, instead of being inactive all the time, in such a manner that the use frequency of the three-way catalyst is made to be equal between the active and inactive cylinder groups.

This method, however, requires frequent switching between the cylinder groups depending on the relationship with respect to the catalyst temperature, requiring switchovers even during the partial cylinder mode resulting in discontinuous combustion relative to the ignition sequence, which leads to a potential deteriorating driving feeling (shock generation) during the switchover period.

In order to address these problems, this invention is designed to improve the driving feeling of a variable cylinder system engine by installing oxygen sensors and three-way catalysts at the exhaust passages of the active cylinder group and in-active cylinder group, and installing a three-way catalyst and an oxygen sensor in the merged section of the exhaust passage downstream of the exhaust passages from the two groups of cylinders mentioned above. In this manner, even during the partial cylinder mode, the temperature of the three-way catalyst in the merged passage can be maintained at an acceptable degree even during the partial cylinder mode so that the switching between the inactive cylinder group and active cylinder group can be made when the engine operation is switched from the full cylinder mode, during which the driving feeling has not deteriorated, to the partial cylinder mode. Next, during the partial cylinder mode, the inactive cylinder group is switched to the active cylinder group. In this manner, the system invented herein can provide switching between the active and inactive cylinder groups in the multi-cylinder variable cylinder system engine that satisfies both the exhaust emission control performance and the smooth driving requirement.

Explained below using drawings are working examples of this invention.

In these working examples, an electronically controlled 6-cylinder fuel injection engine is used in which the number of fuel-supplied cylinders is controlled by the pattern indicated in Fig. 2.

In Fig. 1, 1 is the engine, 1a is the intake passage, 1b and 1c are the divided exhaust passages for cylinders $\phi 1 \sim \phi 3$ and cylinders $\phi 4 \sim \phi 6$, respectively, and 1d is the merged exhaust passage of these two divided passages.

Located in exhaust passages 1b, 1c, and 1d are three-way catalysts, 2, 3, and 4, respectively, and oxygen sensors, 5, 6, and 7, respectively. The outputs from oxygen sensors 5 ~ 7 are, as indicated in Fig. 3, sent to a fuel injection control circuit (EGI circuit, hereafter), 11, through an air-fuel ratio control circuit, 17, from a switching circuit, 16, as the air-fuel ratio correction signal. As explained later, the air-fuel ratio of the air-fuel mixture supplied to the engine is feedback controlled to be approximately equal to the stoichiometric air-fuel ratio.

EGI circuit 11 described above outputs the fuel injection signal simultaneous with the engine rpm, having a pulse width corresponding essentially to the intake airflow that is based on outputs from engine intake air flow rate sensor 9 and engine speed sensor 10. This output signal is corrected by the

feedback signal, mentioned above, before it is supplied to fuel injection valve 13 for $\phi 1 \sim \phi 3$ cylinders and fuel injection valve 14 for $\phi 4 \sim \phi 6$ cylinders through the variable cylinder system control circuit (VCS circuit, hereafter), 12.

VCS circuit 12 mentioned above performs the control function, as indicated in Fig. 2, in such a manner that it selectively shuts off the fuel supply to cylinders $\phi 1 \sim \phi 3$ or to cylinders $\phi 4 \sim \phi 6$ under a light engine load condition, and supplies fuel to all cylinders (6 cylinders) under a heavy load condition. The status-quo region (in Fig. 2) represents the hysteresis region for preventing hunting during the period when the cylinder groups are switched over.

Based on the signal from the throttle switch, 8, the full cylinder mode restoration rpm is decreased from No to No' during the time the throttle valve is fully closed.

VCS circuit 12 is configured as that shown in Fig. 4. In this figure, 25 and 26 pulse width comparators, which compare the output of comparison standard voltage generator 27 for a heavy load (P_{WH}) and the output of comparison standard voltage generator 28 for a light load (P_{WL}), with the output of the fuel injection pulse signal, P_W, If the latter is greater than the respective standard values, VCS circuit 12 outputs the high level signal, "1." A flip-flop, 33, permits input of the output of comparator 25 to the J-terminal, and input of the output of comparator 26 to the K -terminal through a sign inverter, 29, so that the sign of these outputs are changed. The number of cylinders is determined based on the output of flip-flop 33. In principle, output Q becomes "1" for the 6-cylinder signal when $P_W > P_{WH}$, and output $\overline{Q}$ becomes "1" for the 3-cylinder signal when $P_W < P_{WL}$.

A comparator, 31, to which the voltage, V_N, corresponding to the engine rpm is input through an F-V converter (frequency-voltage converter), 30, compares the V_N with output V_{NO} from the rpm standard voltage generator, 32. If it is found that $V_{NO} > V_N$, "1" is input to the S-terminal (set terminal) of flip-flop 33 so that output Q is restored to "1" for the 6-cylinder operation irrespective of pulse width P_W.

In addition, the rpm standard voltage generator 32, when the "fully closed" signal is input from throttle switch 8, switches its generated standard voltage from V_{NO} to V_{NO}' causing the rpm for the 6-cylinder restoration to decrease further.

Flip-flop 34 is designed to switch the inactive cylinder group over to the group consisting of $\phi 1 \sim \phi 3$ cylinders or to the group consisting of $\phi 4 \sim \phi 6$ cylinders every time the running condition becomes the

6-cylinder mode. Every time output Q of flip-flop 33 mentioned above becomes "1," outputs Q and $\overline{Q}$ are mutually inverted in such a manner that if one becomes "1," the other becomes "0." By forcing outputs Q and $\overline{Q}$ to be input to the "AND" circuits, 35 and 36, the group of inactive cylinders, for which the fuel supply is cut-off, is switched. When the output of $\overline{Q}$ of flip-flop 33 becomes "1," either outputs Q or $\overline{Q}$ of flip-flop 34, whichever outputs the signal "1," opens the gate. This leads to the sending of "1" for the 3-cylinder signal to the normally closed analog switches (normally closed relay), 37 or 38, to open the relay contact point.

Analog switch 37 is inserted into the circuit that provides the fuel injection signal to fuel injection valve 13 for $\phi 1 \sim \phi 3$ cylinders, while analog switch 38 is inserted into the circuit that provides the fuel injection signal to fuel injection valve 14 for $\phi 4 \sim \phi 6$ cylinders.

Consequently, since output $\overline{Q}$ of flip-flop 33 is "0," during the 6-cylinder operation, both analog switches 37 and 38 are in the state in which the relay contact points are closed. If, however, the 3-cylinder signal "1" is output as output Q, the relay contact point of either one of analog switches 37 or 38 is turned off, causing the operation of either the $\phi 1 \sim \phi 3$ cylinder group or the $\phi 4 \sim \phi 6$ cylinder group to become inactive.

As explained earlier, this switching is achieved only during the 6-cylinder operation because outputs Q and $\overline{Q}$ are inverted to open either one of the gates for the AND circuits 35 or 36 alternately every time flip-flop 34 inputs "1," which is the 6-cylinder signal for output Q of flip-flop 33 in the previous step.

Next, the variable cylinder system control signals, a and b, from VCS circuit 12 are input to a delay circuit, 15, depicted in Figs. 3 and 5, to activate switching circuit 16 for the outputs of oxygen sensors 5 ~ 7.

Here, the normally closed analog switches (normally closed relays), 39 and 40, and 41 and 42, in switching circuit 16 are turned on when variable cylinder signals "a" and "b" become "1" (the exception being that switches 39 and 42 will be turned on when signals "a" and "b" become "0," because of the presence of sign inverters, 43 and 44.)

Consequently when the variable cylinder signals "a" and "b" mentioned above are input to switching circuit 16 through delay circuit 15 after a specified time delay, the output of oxygen sensor 5 or 7 is

selected corresponding to these signals before being input to comparator18 in air-fuel ratio control circuit 17.

Specifically, since variable cylinder signal "b" is "1" when cylinders $\phi 1 \sim \phi 3$ are inactive, analog switch 40 is turned off while switch 39 is turned on. At the same time, since variable cylinder signal "a" is "0," analog switch 41 is turned on and switch 42 is turned off, causing the output of oxygen sensor 5 to be selected to perform feedback control of the air-fuel ratio, which is explained later, for $\phi 4 \sim \phi 6$ cylinders.

Similarly when cylinders $\phi 4 \sim \phi 6$ are inactive, analog switches 40 and 41 are turned on to perform feedback control of the air-fuel ratio for cylinders $\phi 1 \sim \phi 3$ based on the output from oxygen sensor 6 for cylinders $\phi 1 \sim \phi 3$. During the full cylinder operation, only analog switch 42 is turned on to perform feedback control for all cylinders based on the output of oxygen sensor 7 located in merged passage 1d.

The reason a specified time delay is provided for switching the outputs of oxygen sensors $5 \sim 7$ is to take into consideration the time needed for the combustion gas to reach oxygen sensors $5 \sim 7$ during the cylinder switching period. If switching circuit 16 is activated simultaneously with the cylinder switching, although momentarily, there is a possibility that the oxygen concentration of the exhaust gas from the inactive cylinders will be detected. This would lead to creating a potential risk of causing confusion in the feedback control as indicated earlier. The time delay assures that this problem will be prevented from occurring.

Next, air-fuel ratio control circuit 17 is designed to output an air-fuel ratio correction signal to EGI circuit 11 mentioned earlier based on the output of oxygen sensors $5 \sim 7$ so that the feedback control is performed to obtain an air-fuel ratio close to the stoichiometric air-fuel ratio.

Number 19 represents a standard voltage generator that outputs the standard voltage corresponding to the stoichiometric air-fuel ratio, while number 18 is a comparator that compares this standard voltage with the output of the oxygen sensors mentioned above. Number 20 represents a correction circuit that outputs a correction signal based on deviation of the outputs of comparator 18 and the established standard signal. Number 22 represents, as described later, a clamp *(phon)* circuit to hold the output value at a constant value by interrupting the feedback control based on the outputs of monitor circuit

21 that determines the output condition of the oxygen sensors, and based on the full throttle signal from full throttle switch 24, or based on the fuel-cut signal during deceleration. In addition, monitor circuit 21 activates clamp circuit 22 to interrupt the feedback control as mentioned above when the temperatures of oxygen sensors 5~7 become too low to generate an appropriate output, or when the start signal is received from the starter switch, 23.

With the configuration explained above, when cylinders $\phi 1 \sim \phi 3$ are active, air-fuel ratio feedback control is performed based on the output of oxygen sensor 6, which permits fuel injection valve 13 to inject fuel so that an air-fuel mixture close to the stoichiometric value can be supplied to cylinders $\phi 1 \sim \phi 3$.

Consequently, three-way catalyst 3 can achieve high efficiency oxidation of HC and CO as well as reduction of NOx at the same time.

For the other three-way catalyst, 2, during this period, since the exhaust air from cylinders $\phi 4 \sim \phi 6$ is flowing into it, there is a possibility that its temperature might decrease. But, for three-way catalyst 4 located downstream, since the mixture of the combustion exhaust gas from cylinders $\phi 1 \sim \phi 3$ and the non-combustion exhaust gas from cylinders $\phi 4 \sim \phi 6$ is flowing into it, the temperature reduction will be relatively lower than that of three-way catalyst 3 located upstream. As a result, when the engine operation is shifted to the full cylinder mode, and even when the reaction of three-way catalyst 2 for cylinders $\phi 4 \sim \phi 6$ is low, three-way catalyst 4 in merged passage 1d can instantly achieve a highly efficient reaction.

Needless to say, feedback control of the air-fuel ratio can be achieved at the same time based on the output of oxygen sensor 7 located in merged passage 1d.

Moreover, since cylinder group switching is performed for every 6-cylinder operation, when it is followed by the 3-cylinder operation, the group consisting of cylinders $\phi 4 \sim \phi 6$, which has been inactive, becomes active while the group consisting of cylinders $\phi 1 \sim \phi 3$ becomes inactive.

Since cylinder group switching is performed in this manner, except when the partial cylinder operation lasts for a very long time, there is almost no possibility that the temperatures of upstream three-way catalysts 2 or 3 will decrease significantly.

Moreover, during the full cylinder operation, the purification (reaction) of harmful components in the exhaust gas takes place not only in downstream three-way catalyst 4, but also in upstream three-

way catalysts 2 and 3. This actually results in a marked decrease in the load on three-way catalyst 4, which permits decreasing the capacity of three-way catalyst 4.

Next, the working example shown in Fig. 6 is a system in which the generated voltage is switched by inputting variable cylinder signal "a" to standard voltage generator 19' in such a manner that the target air-fuel ratio for feedback control during the 3-cylinder operation is slightly lower than the stoichiometric air-fuel ratio.

In addition, the working example shown in Fig. 7 is a system in which upstream oxygen sensors 5 and 6 are eliminated, air-fuel ratio feedback control is interrupted during the 3-cylinder operation, and the specified air-fuel ratio is set at a value that is slightly lower than the stoichiometric air-fuel ratio. In order to achieve this control, the feedback control is interrupted and it is switched to a rich air-fuel ratio when variable cylinder control signal "a" is input to a clamp circuit, 22'.

In all of these working examples, the air fuel ratio is set slightly lower than the stoichiometric value to achieve NOx reduction efficiency of the upstream three-way catalysts 2 and 3 as high as possible during the 3-cylinder operation, while at the same time HC and CO can be oxidized under a sufficient amount of oxygen at three-way catalyst 4 in the merged passage, which leads to further improvement of exhaust emission control efficiency.

As explained above, according to this invention, it is no longer necessary to switch the cylinder groups during partial cylinder operation, which tends to worsen the driving feeling, resulting in improvement in driving performance. There is also another outstanding effect, thanks to the activity of the three-way catalyst placed in the merged exhaust passage, of preventing temporary deterioration of the exhaust characteristics that tend to occur when the engine operation is switched from the partial cylinder mode to the full cylinder mode.

Brief Explanation of Drawings

Fig. 1 is an approximate plan view of this invention. Fig. 2 explains the variable cylinder control pattern. Fig. 3 is a block diagram of the variable cylinder system for working example No.1, while Fig. 4 is a block diagram of its variable cylinder system circuit. Fig. 5 is a block diagram of the switching circuit. Figs. 6 and 7 are block diagrams of the control systems for other working examples

of this invention.

1. . . Engine Body

1b and 1c. . . Exhaust Passage

1d. . . Merged Exhaust Passage

2, 3, and 4. . . Three-Way Catalysts

5 , 6, and 7. . . Oxygen Sensors

11. . . Fuel Injection Control Circuit

12. . . VCS Circuit

15. . . Delay Circuit

16. . . Switching Circuit

17 . . . Air-Fuel Ratio Control Circuit

Patent Applicant: Nissan Motor Company, Ltd.

Agent: Patent Attorney: Masayoshi Goto

FIGURES

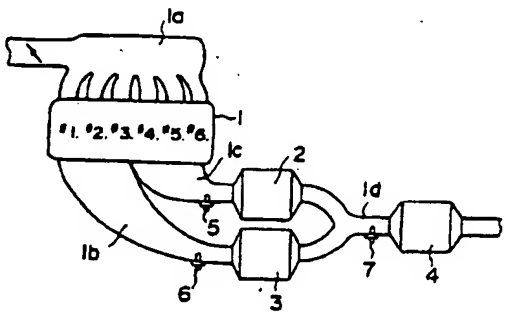

Fig. 1

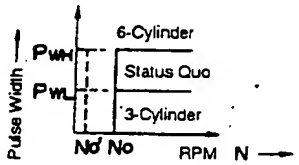

Fig. 2

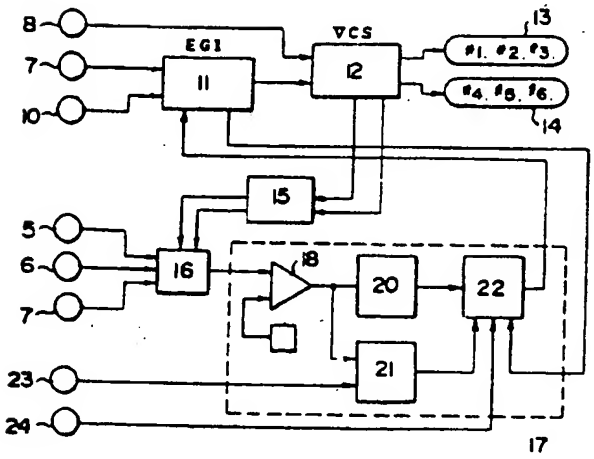

Fig. 3

FIGURES

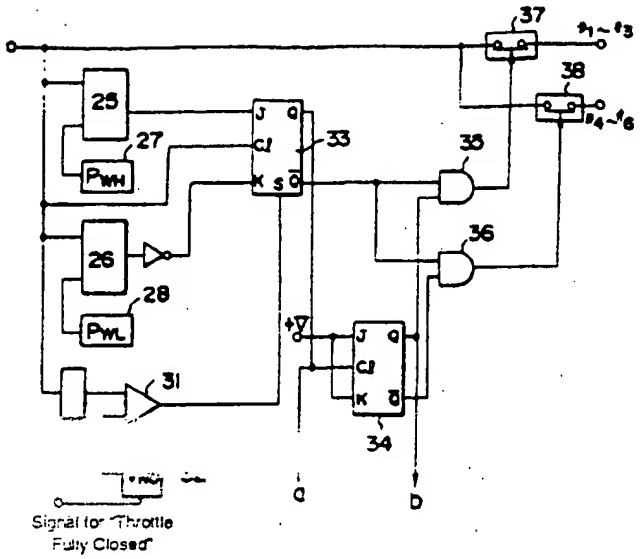

Fig. 4

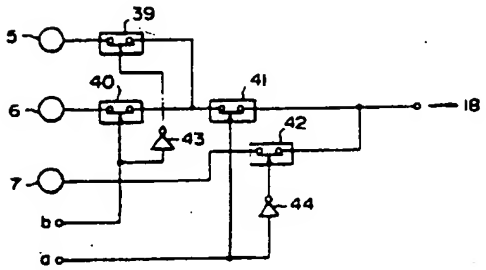

Fig. 5

FIGURES

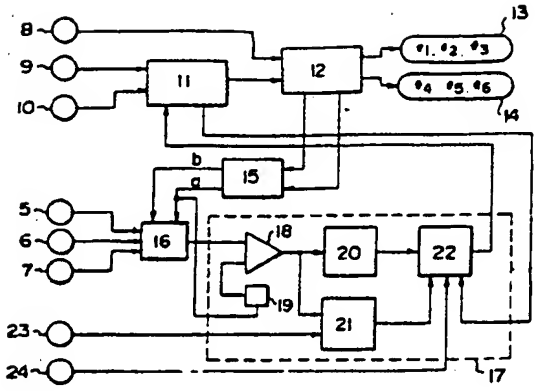

Fig. 6

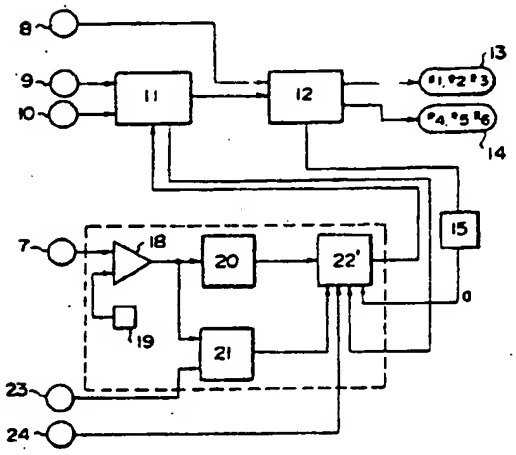

Fig. 7